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UTILITY PATENT APPLICATION TRANSMITTAL *(Only for new nonprovisional applications under 37 CFR 1 53(b))*	Attorney Docket No.	9438-0014-2
	First Inventor or Application Identifier	Hiroyuki KANO
	Title	LIGHT-RECEIVING DEVICE WITH QUANTUM-WAVE INTERFERENCE LAYERS

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APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents

ADDRESS TO: Assistant Commissioner for Patents
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1. ■ Fee Transmittal Form (e.g. PTO/SB/17) (Submit an original and a duplicate for fee processing)
2. ■ Specification Total Pages **34**
3. ■ Drawing(s) *(35 U.S.C. 113)* Total Sheets **10**
4. ■ Oath or Declaration Total Pages **3**
   - a. ■ Newly executed (original)
   - b. □ Copy from a prior application *(37 C.F.R. §1.63(d))* *(for continuation/divisional with box 15 completed)*
     - i. □ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see *37 C.F.R. §1.63(d)(2) and 1.33(b).*
5. □ Incorporation By Reference *(usable if box 4B is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4B, is considered to be part of the disclosure of the accompanying application and is hereby incorporated by reference therein.

ACCOMPANYING APPLICATION PARTS

6. ■ Assignment Papers (cover sheet & document(s))
7. □ 37 C.F.R. §3.73(b) Statement *(when there is an assignee)* □ Power of Attorney
8. □ English Translation Document *(if applicable)*
9. □ Information Disclosure Statement (IDS)/PTO-1449 □ Copies of IDS Citations
10. □ Preliminary Amendment
11. ■ White Advance Serial No. Postcard
12. ■ Small Entity Statement(s) □ Statement filed in prior application. Status still proper and desired.
13. ■ Certified Copy of Priority Document(s) (1) *(if foreign priority is claimed)*
14. ■ Other: Notice of Priority

15. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below:*
□ Continuation □ Divisional □ Continuation-in-part (CIP) of prior application no.:
Prior application information: Examiner: Group Art Unit:

16. Amend the specification by inserting before the first line the sentence:
□ This application is a □ Continuation □ Division □ Continuation-in-part (CIP) of application Serial No. Filed on
□ This application claims priority of provisional application Serial No. Filed

17. CORRESPONDENCE ADDRESS

OBLON, SPIVAK, MCCLELLAND, MAIER & NEUSTADT, P.C.
FOURTH FLOOR
1755 JEFFERSON DAVIS HIGHWAY
ARLINGTON, VIRGINIA 22202
(703) 413-3000
FACSIMILE: (703) 413-2220

Name:	Marvin J. Spivak	Registration No.:	24,913
Signature:	C. Irvin McClelland (signature)	Date:	12/16/99
Name:	C. Irvin McClelland ~~Registration Number 21,124~~	Registration No.:	

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OBLON, SPIVAK, McCLELLAND, MAIER & NEUSTADT, P.C.

Applicant or Patentee: Hiroyuki KANO
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Filed or Issued: HEREWITH
For: LIGHT-RECEIVING DEVICE WITH QUANTUM-WAVE INTERFERENCE LAYERS

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I hereby declare that I am

( ) the owner of the small business concern identified below:
(xx) an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN CANARE ELECTRIC CO., LTD.
ADDRESS OF CONCERN 2888-1 Rikka, Kumabari, Nagakute-cho, Aichi-gun, Aichi-ken, 480-1101, JAPAN

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

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( ) patent no. ____________, issued ____________.

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NAME OF PERSON SIGNING Hiroyuki KANO
TITLE OF PERSON OTHER THAN OWNER Director
ADDRESS OF PERSON SIGNING 18B3, 1237-87, Umazutsumi, Kurozasa, Miyoshi-cho, Nishikamo-gun, Aichi-ken, 470-0201, JAPAN
SIGNATURE Hiroyuki Kano DATE 26/Nov/99

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LIGHT-RECEIVING DEVICE WITH

QUANTUM-WAVE INTERFERENCE LAYERS

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to an opto-electric conversion device with a new structure, or a light-receiving device.

Description of the Related Art

A light-receiving device has been known to have a pin junction structure. A backward voltage is applied to the pin layers of the device, and electron-hole pairs are generated by that light incided from the side of a p-layer is absorbed in an i-layer. The electron-hole pairs excited in the i-layer are accelerated by a backward voltage in the i-layer, and electrons and holes are flowing into an n-layer and a p-layer, respectively. Thus a photocurrent whose intensity varies according to an intensity of the incident light is outputted.

To improve an opto-electric conversion effectivity, the i-layer which absorbs light is formed to have a comparatively larger thickness. But when the thickness of the i-layer becomes thicker, more times are needed to draw carriers to the n-layer and the p-layer. As a result, the response velocity of the opto-electric conversion is lowered. To improve the velocity, an electric field in the

i-layer is increased by increasing a backward voltage. But when the backward voltage is enlarged, an element separation become difficult and a leakage current is occurred. As a result, an photocurrent which flows when the device is not incided by light, or a dark current, is increased.

Thus conventional light-receiving devices had an interrelation among a light-receiving sensitivity, a detecting velocity, and a noise current, which restricts their performances.

SUMMARY OF THE INVENTION

It is, therefore, an object of the present invention to improve the light-receiving sensitivity and the response velocity of the opto-electric conversion by providing a light-receiving device having a pin junction of a completely new structure.

In light of these objects a first aspect of the present invention is a light-receiving device, which converts incident light into electric current, constituted by a quantum-wave interference layer units having plural periods of a pair of a first layer and a second layer, the second layer having a wider band gap than the first layer, and a carrier accumulation layer disposed between adjacent two of the quantum-wave interference layer units. Each thickness of the first and the second layers is determined by multiplying by an even number one fourth of a quantum-

wave wavelength of carriers in each of the first and the second layers, and the carrier accumulation layer has a band gap narrower than that of said second layer. Plural units of the quantum-wave interference layers are formed with a carrier accumulation layer, which has a band gap narrower than that of the second layer, lying between each of the quantum-wave interference units.

The second aspect of the present invention is to set a kinetic energy of the carriers, which determines the quantum-wave wavelength, at the level near the bottom of a conduction band when the carriers are electrons or at the level near the bottom of a valence band in the second layer when the carriers are holes.

The third aspect of the present invention is to define each thickness of the first and the second layers as follows:

$$D_W = n_W \lambda_W/4 = n_W h/4[2m_W(E+V)]^{\frac{1}{2}} \quad \ldots(1)$$

and

$$D_B = n_B \lambda_B/4 = n_B h/4(2m_B E)^{\frac{1}{2}} \quad \ldots\ (2)$$

In Eqs. 1 and 2, h, m_W, m_B, E, V, and n_W, n_B represent Plank's constant, the effective mass of carrier conducting in the first layer, the effective mass of carriers in the second layer, the kinetic energy of the carriers at the level near the lowest energy level of the second layer, the potential energy of the second layer relative to the first layer, and even numbers, respectively.

The fourth aspect of the present invention is a

quantum-wave interference layer having a partial quantum-wave interference layers I_k with arbitrary periods T_k including a first layer having a thickness of $n_{Wk}\lambda_{Wk}/4$ and a second layer having a thickness of $n_{Bk}\lambda_{Bk}/4$ for each of a plural different values E_k, E_k+V. E_k, E_k+V, λ_{Bk}, λ_{Wk}, and n_{Bk}, n_{Wk} represent a kinetic energy of carriers conducted in the second layer, a kinetic energy of carriers conducted in the first layer, a quantum-wave wavelength corresponding energies of the second layer and the first layer, and even numbers, respectively.

The fifth aspect of the present invention is to form a carrier accumulation layer having the same bandwidth as that of the first layer.

The sixth aspect of the present invention is to form a carrier accumulation layer having a thickness same as its quantum-wave wavelength λ_W.

The seventh aspect of the present invention is to form a δ layer between the first layer and the second layer, which sharply varies band gap energy at the boundary between the first and second layers and is substantially thinner than that of the first and the second layers.

The eighth aspect of the present invention is a light-receiving device having a pin junction structure, and the quantum-wave interference layer and the carrier accumulation layer are formed in the i-layer.

The ninth aspect of the present invention is to form the quantum-wave interference layer and the carrier

accumulation layer in the n-layer or the p-layer.

The tenth aspect of the present invention is a light-receiving device having a pin junction structure.

First to third, and eighth to tenth aspects of the invention

The principle of the light-receiving device of the present invention is explained hereinafter. FIG. 1 shows an energy diagram of a conduction band and a valence band when an external voltage is applied to the interval between the p-layer and the n-layer in a forward direction. As shown in FIG. 1, the conduction band of the i-layer becomes plane by applying the external voltage. Four quantum-wave interference layer units Q_1 to Q_4 are formed in the i-layer, and carrier accumulation layers C_1 to C_3 are formed at each intervals of the quantum-wave interference layer units. FIG. 2 shows a conduction band of a quantum-wave interference layer unit Q_1 having a multi-layer structure with plural periods of a first layer W and a second layer B as a unit. A band gap of the second layer B is wider than that of the first layer W.

Electrons conduct from left to right as shown by an arrow in FIG. 2. Among the electrons, those that exist at the level near the lowest energy level of a conduction band in the second layer B are most likely to contribute to conduction. The electrons near the bottom of conduction band of the second layer B has a kinetic energy E. Accordingly, the electrons in the first layer W have a

kinetic energy E+V which is accelerated by potential energy V due to the band gap between the first layer W and the second layer B. In other words, electrons that move from the first layer W to the second layer B are decelerated by potential energy V and return to the original kinetic energy E in the second layer B. As explained above, kinetic energy of electrons in the conduction band is modulated by potential energy due to the multi-layer structure.

When thicknesses of the first layer W and the second layer B are equal to order of quantum-wave wavelength, electrons tend to have characteristics of a wave. The wave length of the electron quantum-wave is calculated by Eqs. 1 and 2 using kinetic energy of the electron. Further, defining the respective wave number vector of first layer W and second layer B as K_W and K_B, reflectivity R of the wave is calculated by:

$$R = (|K_W|-|K_B|) / (|K_W|+|K_B|)$$
$$= ([m_W(E+V)]^{½}-[m_BE]^{½}) / ([m_W(E+V)]^{½}+[m_BE]^{½})$$
$$= [1-(m_BE/m_W(E+V))^{½}] / [1+(m_BE/m_W(E+V))^{½}] \quad \ldots (3).$$

Further, when $m_B = m_W$, the reflectivity R is calculated by:

$$R = [1-(E/(E+V))^{½}]/[1+(E/(E+V))^{½}] \quad \ldots (4).$$

When $E/(E+V) = x$, Eq. 4 is transformed into:

$$R = (1-x^{½}) / (1+x^{½}) \quad \ldots (5).$$

The characteristic of the reflectivity R with respect to the energy ratio x obtained by Eq. 5 is shown in FIG. 3.

When the condition $x \leq 1/10$ is satisfied, $R \geq 0.52$.

Accordingly, the relation between E and V is satisfied with:

$E \leqq V/9$ ... (6).

Since the kinetic energy E of the conducting electrons in the second layer B exists near the bottom of the conduction band, the relation of Eq. 6 is satisfied and the reflectivity R at the interface between the second layer B and the first layer W becomes 52 % or more. Consequently, the multi-layer structure having two kinds of layers with band gaps different from each other enables to reflect quantum-wave of electrons which is injected to an i-layer.

Further, utilizing the energy ratio x enables the thickness ratio D_B/D_W of the second layer B to the first layer W to be obtained by:

$D_B/D_W = [m_W / (m_B x)]^{\frac{1}{2}}$ ... (7).

When thicknesses of the first and second layers are determined by multiplying an even number by one fourth of a quantum-wave wavelength, or by a half of a quantum-wave wavelength, for example, a standing wave rises in a quantum-wave interference layer, and a resonant conduction is occurred. That is, when a quantum-wave period of the standing wave and a potential period of the quantum-wave interference layer is corresponded to each other, a scattering of the carrier in each layer is suppressed, and a conduction of a high mobility is realized.

When light is incided to the i-layer formed in the light-receiving device, electrons excited in conduction bands of the carrier accumulation layers C_1, C_2 and C_3 are

accumulated therein. The excited electrons tend to flow to the p-layer by the applied forward voltage. But the energy which the excited electrode have is lower than the bottom of the conduction band in the second layer B. Accordingly, the electrons do not flow because a transmission condition is not satisfied for electrons in the quantum-wave interference layer unit which exists at the side toward the p-layer.

But when the electrons existing in the carrier accumulation layers C_1, C_2 and C_3 are increased, electrons tend to exist in higher level. Then a kinetic energy of the electrons existing in higher level increases, and the electrons can highly conduct or transmit in the quantum-wave interference layer units because of satisfaction of the transmission condition. As a result, the electrons passes the quantum-wave interference layer units Q_2, Q_3, and Q_4 and flow toward the p-layer, which occurs a photocurrent.

Because a forward voltage is applied to the light-receiving device, driving at a low voltage becomes possible and an element separation become easier. When light is not incided, electrons does not have a high transmittivity in the quantum-wave interference layer units. As a result, a dark current can be lowered. The present inventor thinks that electrons is conducted in the quantum-wave interference layer units as a wave. Accordingly, a response velocity is considered to become larger.

Thicknesses of the first layer W and the second layer B are determined for selectively transmitting one of holes

and electrons, because of a difference in potential energy V between the valence and the conduction bands, and a difference in effective mass of holes and electrons in the first layer W and the second layer B. Namely, the optimum thickness of the first and the second layers for transmitting electrons is not optimum for transmitting holes. Eqs. 5-9 refer to a structure of the quantum-wave interference layer for transmitting electrons selectively. The thickness for selectively transmitting electrons is designed based on the potential difference in the conduction band and effective mass of electrons. Consequently, the quantum-wave interference layer has a high transmttivity (or a high mobility) for electrons, but not for holes.

Further, the thickness for selectively transmitting holes is designed based on a difference in potential energy of the valence band and effective mass of holes, realizing another type of quantum-wave interference layer as a hole transmission layer, which has a high mobility for holes and which has an ordinary mobility for electrons.

Further explanation can be obtained by FIGS. 4A-4H. FIGS. 4A-4H illustrate the relationship between quantum-wave reflection of electrons in a potential of quantum-well structure and a period of potential representing a conduction band of a multi quantum-well (MQW). FIGS. 4A-4D show the relationship when the period, i.e., width of the second layer B or the first layer W, of the potential is equal to an odd number multiplied by one fourth of the

wavelength of propagated electron. This type of the potential is named as $\lambda/4$ type potential hereinafter. FIGS. 4E-4H show when the period of the potential is equal to a natural number multiplied by a half of the wavelength of propagated electron. This type of the potential is named as $\lambda/2$ type potential hereinafter. In order to make it visually intelligible, thickness of each layers is unified in FIGS. 4A-4H. Electrons existing around the bottom of the second layer B conduct from left to right as shown by an arrow in FIGS. 4A and 4E. And in FIGS. 4B and 4F, the electrons reach the interface between the first layer W and the second layer B.

When the quantum-wave of the electrons reaches the interface between the second layer B and the first layer W in the $\lambda/4$ type potential, a transmission wave QW2 and a reflection wave QW3 having a phase equal to that of the transmission wave QW2, are generated with respect to an incident wave QW1 as shown in FIG. 4C. Then when the transmission wave QW2 reaches the interface between the first layer W and the second layer B, a transmission wave QW4 and a reflection wave QW5 having a phase opposite to that of the transmission wave QW4 are generated as shown in FIG. 4D. The relationship between phases of the transmission wave and the reflection wave at the interface depends on following or rising of a potential of the conduction band at the interface. In order to make it visually intelligible, each amplitudes of QW1, QW2, QW3,

QW4, and QW5 is unified in FIGS. 4A-4H.

With respect to the $\lambda/4$ type potential of the multi quantum-well, the propagating quantum-wave of electrons represented by QW1, QW2 and QW4 and the reflecting quantum-wave of electrons represented by QW3 and QW5 cancels with each other, as shown in FIG. 4D. The quantum-wave of electrons represented by the QW1, QW2 and QW4 propagates from left to right, and the quantum-wave of electrons represented by the QW3 and QW5, generated by the reflection at two interfaces, propagates from right to left. Accordingly, a multi quantum-well, having a potential which is formed in a period, i.e., the width of the first layer W and the second layer B, determined by multiplying by an odd number one fourth of quantum-wave wavelength of propagated electrons, cancels the quantum-wave of electrons. In short, the multi quantum-well functions as a reflection layer which does not propagate electrons.

With respect to a multi quantum-well, having a potential which is formed in a period, i.e., the width of the first layer W and the second layer B, determined by multiplying by an even number one fourth of quantum-wave wavelength of propagated electrons, i.e., $\lambda/2$ type potential, as shown in FIGS. 4E-4H, the quantum-wave of electrons can become a standing wave.

Similarly, when a quantum-wave of electrons reaches the interface between the second layer B and the first layer W in the $\lambda/2$ type potential, a transmission wave QW2 and a

reflection wave QW3 having a phase corresponding to that of the transmission wave QW2, are generated with respect to an incident wave QW1 as shown in FIG. 4G. Then when the transmission wave QW2 reaches the interface between the first layer W and the second layer B, a transmission wave QW4 and a reflection wave QW5 having a phase opposite to that of the transmission wave QW4 are generated as shown in FIG. 4H. With respect to $\lambda/2$ type potential of the multi quantum-well, the propagating quantum-wave of electrons represented by QW1, QW2 and QW4 and the reflecting quantum-wave of electrons represented by QW5 intensifies to each other, as shown in FIG. 4H. On the other hand, the reflection waves QW3 and QW5 can be considered to cancel with each other and the quantum-wave of electrons which is propagated from left to right in FIG. 4E can be a standing wave. Accordingly, with respect to the multi quantum-well, having a potential which is formed in a period, i.e., the width of the first layer W and the second layer B, determined by multiplying by an even number one fourth of quantum-wave wavelength of propagated electrons, the quantum-wave of electrons can become a standing wave and a transmission layer having a high transmittivity (or a high mobility) for electrons can be realized.

Alternatively, a multi quantum-well, having a potential which is formed in a period determined by multiplying by a natural number half of quantum-wave wavelength of holes, can be applied to the relationship

described above.

The quantum-wave interference layer unit described above can transmit carriers in accordance with numbers of electrons accumulated in the carrier accumulation layer. Accordingly, the light-receiving device can be formed by only one of the n-layer and the p-layer in which the quantum-wave interference layer units and the carrier accumulation layer are formed. Alternatively, the light-receiving device can be formed by a pn junction structure, in which the quantum-wave interference layer units and the carrier accumulation layer are formed in at least one of n-layer and p-layer.

Fourth aspect of the present invention

FIG. 5 shows a plurality quantum-wave interference units I_k with arbitrary periods T_k including a first layer having a thickness of D_{Wk} and a second layer having a thickness of D_{Bk} and arranged in series.

Each thickness of the first and the second layers satisfies the formulas:

$$D_{Wk} = n_{Wk}\lambda_{Wk}/4 = n_{Wk}h/4[2m_{Wk}(E_k+V)]^{1/2} \qquad \ldots(8)$$

and

$$D_{Bk} = n_{Bk}\lambda_{Bk}/4 = n_{Bk}h/4(2m_{Bk}E_k)^{1/2} \qquad \ldots(9)$$

In Eqs. 8 and 9, E_k, m_{Wk}, m_{Bk}, and n_{Wk} and n_{Bk} represent plural kinetic energy levels of carriers conducted into the second layer, effective mass of carriers with kinetic energy E_k+V in the first layer, effective mass of carriers with

kinetic energy E_k in the second layer, and arbitrary even numbers, respectively.

The plurality of the partial quantum-wave interference layers I_k are arranged in series from I_1 to I_j, where j is a maximum number of k required to form a quantum-wave interference layer as a whole. The carriers existing in a certain consecutive energy range can be effectively transmitted by narrowing a discrete intervals.

Fifth and Sixth aspects of the present invention

The fifth aspect of the present invention is to form the band width of the carrier accumulation layer to have the same bandwidth as that of the first layer. And the sixth aspect of the present invention is to form the carrier accumulation layer to have a thickness same as its quantum-wave wavelength λ_W. As a result, the carriers excited in the carrier accumulation layer can be confined effectively.

Seventh aspect of the present invention

The seventh aspect of the present invention is directed forming a δ layer at the interface between the first layer W and the second layer B. The δ layer has a relatively thinner thickness than both of the first layer W and the second layer B and sharply varies an energy band. By sharply varying the band gap of the interfaces, the potential energy V of an energy band becomes larger substantially and the value x of Eq. 5 becomes smaller, as

shown in FIGS. 7A-7D. Without forming a δ layer as shown in FIG. 7A, a part of component of the first layer W and the second layer B mixes when the second layer B is laminated on the first layer W, and an energy band gap which varies sharply cannot be obtained, as shown in FIG. 7B. When a δ layer is formed at each interfaces of the first and the second layers, as shown in FIG. 7C, even if a part of component of the first layer W and the second layer B mixes, an energy band gap varies sharply compared with the case without δ layers, as shown in FIG. 7D.

Variations are shown in FIGS. 6A to 6D. The δ layer may be formed on both ends of the every first layer W as shown in FIGS. 6A to 6D. In FIG. 6A, the δ layers are formed so that an energy level higher than that of the second layer B may be formed. In FIG. 6B, the δ layers are formed so that a band having lower bottom than that of the first layer W may be formed. In FIG. 6C, the δ layers are formed so that the energy level higher than that of the second layer B and the energy level lower than that of the first layer W may be formed. As an alternative to each of the variations shown in FIGS. 6A to 6C, the δ layer can be formed on one end of the every first layer W as shown in FIG. 6D.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features, and characteristics of the

present invention will become apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of the specification, and wherein reference numerals designate corresponding parts in the various figures, wherein:

FIG. 1 is a view showing the energy diagram of a quantum-wave interference layer according to the present invention;

FIG. 2 is an explanatory view of a conduction band of a multi-layer structure of the present invention;

FIG. 3 is a graph showing a relation between an energy ratio x and a reflectivity R;

FIGS. 4A-4H are views of a relationship between quantum-wave reflection and transmission of electrons in a potential of quantum-well structure and a period of potential representing a conduction band of a multi quantum-well (MQW);

FIG. 5 is an explanatory view of partial quantum-wave interference layers I_k;

FIGS. 6A-6D are explanatory views of δ layers according to the present invention;

FIGS. 7A-7D are views showing energy level according to the second and eighth aspects of the present invention;

FIG. 8 is a sectional view showing a structure of a light-receiving device 100 (Example 1);

FIG. 9 is a graph showing measured V-I characteristic

of the light-receiving device 100 when incided or not incided by light; and

FIG. 10 is a graph showing measured V-I characteristic of the light-receiving device 200 when incided not incided by light (Comparative Example).

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will be more fully understood by reference to the following examples.

Example 1

FIG. 8 is a sectional view of a semiconductor device 100 having an pin junction structure in which a quantum-wave interference layer is formed in an i-layer. The light-receiving device 100 has a substrate 10 made of gallium arsenide (GaAs). A GaAs buffer layer 12 of n-type conduction, having a thickness generally of 0.3 μm and an electron concentration of 2 x $10^{18}/cm^3$, is formed on the substrate 10. An n-$Ga_{0.51}In_{0.49}P$ contact layer 14 of n-type conduction, having a thickness generally of 0.13 μm and electron concentration of 2 x $10^{18}/cm^3$, is formed on the buffer layer 12. An n-$Al_{0.51}In_{0.49}P$ n-layer 16 of n-type conduction, having a thickness generally of 0.43 μm and an electron concentration of 1 x $10^{18}/cm^3$, is formed on the contact layer 14. A non-doped i-layer 18 is formed on the n-layer 16. A $Al_{0.51}In_{0.49}P$ p-layer 20 of p-type conduction,

having a thickness generally of 0.43 μm and a hole concentration of 1 x $10^{18}/cm^3$, is formed on the i-layer 18. A p-$Ga_{0.51}In_{0.49}P$ second contact layer 22 of p-type conduction, having a thickness generally of 0.13μm and a hole concentration of 2 x $10^{18}/cm^3$, is formed on the p-layer 20. A p-GaAs first contact layer 24 of p-type conduction, having a thickness generally of 0.06 μm and a hole concentration of 2 x $10^{18}/cm^3$, is formed on the second contact layer 22. An electrode layer 26 made of gold and germanium (Au/Ge), having a thickness generally of 0.2 μm, is formed so as to cover the entire back of the substrate 10. Another electrode layer 28 made of Au/Zn, having a thickness generally of 0.2 μm, is formed on some portion of the first contact layer 24.

A quantum-wave interference unit A_1 having a multi-quantum layer structure with 10 pairs of a $Ga_{0.51}In_{0.49}P$ first layer W, having a thickness of 10 nm, a $Al_{0.51}In_{0.49}P$ second layer B, having a thickness of 14 nm, and a non-doped $Al_{0.33}Ga_{0.33}In_{0.33}P$ δ layer, having a thickness of 1.3 nm, disposed between the first layer W and the second layer B is formed in the i-layer 18. A_2, ... A_4 are formed like A_1, and 4 quantum-wave interference units in total are formed in the i-layer 18. FIG. 6A shows a band structure of the quantum-wave interference layer A_1 in detail. A non-doped $Ga_{0.51}In_{0.49}P$ carrier accumulation layer C_i, having a thickness of 20 nm, is formed between any quantum-wave interference units A_1 and A_{i+1}, respectively. Thicknesses of the first

layer W and the second layer are determined according to Eqs. 1 and 2, respectively, on condition that no external voltage is applied.

The second layers B which contact to the p-layer 20 and the n-layer 16 have thickness of 10 nm, respectively. And the substrate 10 has a diameter of 2.0 inches and the normal direction of its main surface is offset toward the [011] axis by 15 degree from the (100) plane.

The light-receiving device 100 was manufactured by gas source molecular beam epitaxial deposition (GS-MBE) which is an epitaxial growth method under extremely high vacuum condition. GS-MBE is different from a conventional MBE which supplies group III and V elements both from solid state sources. In GS-MBE, group III elements such as indium (In), gallium (Ga), and aluminum (Al) are supplied from a solid source and group V elements such as arsenic (As) and phosphorous (P) are supplied by heat decomposition of gas material such as AsH_3 and PH_3. Alternatively, the light-receiving device 100 can be manufactured by metal organic chemical vapor deposition (MOCVD).

As shown in FIG. 1, as a forward voltage V applied between the p-layer 20 and the n-layer 16 of the light-receiving device 100 increases, an electric potential gradient occurring in the i-layer 18 becomes gentler until it becomes plane. In this condition, electrons do not flow because a transmission condition for electrons in all of quantum-wave interference layers Q_1 to Q_4 is not satisfied.

That is, the electrons transmitted through the quantum-wave interference layer Q_1 are relaxed to a basic level in the carrier accumulation layer C_1 and the carrier in C_1 can not transmit through the quantum-wave interference layer Q_2.

When light having an energy resonant to bandwidth of carrier accumulation layers C_1 to C_3 is incided, electrons are excited in the carrier accumulation layers C_1 to C_3. An electron concentration in the carrier accumulation layers C_1 to C_3 becomes larger, and many electrons become to exist at the levels higher than the bottom of a conduction band in the second layer B. Then electrons in the n-layer 16 are conducted into the carrier accumulation layers C_1 which is adjacent to the n-layer 16, and electrons in the carrier accumulation layers C_1 are conducted into the carrier accumulation layers C_2. Accordingly, electrons intervene each carrier accumulation layers C_i and are conducted to each carrier accumulation layers at a high speed, by wave propagation of electrons as a wave. Thus electrons are conducted from the n-layer 16 to the p-layer 20 by a light excitation at a high speed.

The light-receiving device 100 has a high opto-electric conversion effectivity because electrons, which are excited in the carrier accumulation layers C_1 to C_3, function as a gate-controlled switch toward the conduction of electrons from the n-layer 16 to the p-layer 20. When electrons are not excited in the carrier accumulation layers C_1 to C_3, a condition to transmit electrons is not satisfied in the

quantum-wave interference layers Q_1 to Q_4. But when electrons are excited in the carrier accumulation layers C_1 to C_3, the condition is satisfied and electrons may be conducted in the quantum-wave interference layers Q_1 to Q_4 as a wave. Accordingly, a switching velocity is considered to be larger.

Measured V-I characteristic of the light-receiving device 100 is shown in FIG. 9. When light is incided, the photocurrent is 10^{-7} A at a slight forward voltage. And at 0.8V of forward voltage, the photocurrent rises abruptly to 10^{-5} A. But even if a forward voltage is applied to the device, a dark current is suppressed at a lower value and degree of increasing is also suppressed. And the photocurrent when the diode is incided by light is about hundredfold that of a dark current, when the applied forward voltage is less than 1.2 V, and tenfold when the applied forward voltage is around 1.5 V. The photocurrent and the dark current are represented by A1 and B1, respectively. Additionally, the forward applied voltage at which an electric potential gradient in the i-layer 18 becomes plane is appeared to be 0.5 V. When an applied forward voltage is 0.5 V, the photocurrent is about 1 x 10^{-5} A.

Comparative Example

As a comparative example, a light-receiving device 200 having the same structure as that of the light-receiving device 100 in Example 1 was manufactured. A quantum-wave

interference unit Q_1 having a multi-quantum layer structure with 10 pairs of a $Ga_{0.51}In_{0.49}P$ first layer W, having a thickness of 5 nm, a $Al_{0.51}In_{0.49}P$ second layer B, having a thickness of 7 nm, and a non-doped $Al_{0.33}Ga_{0.33}In_{0.33}P$ δ layer, having a thickness of 1.3 nm, disposed between the first layer W and the second layer B is formed in the i-layer 18. Q_2, … Q_4 are formed like Q_1, and 4 quantum-wave interference units in total are formed in the i-layer 18. FIG. 6A shows a band structure of the quantum-wave interference layer units Q_1 in detail. Non-doped $Ga_{0.51}In_{0.49}P$ carrier accumulation layers C_1 to C_3, each having a thickness of 20 nm, is formed between any quantum-wave interference units Q_1 and Q_{i+1}, respectively. Thicknesses of the first layer W and the second layer B are determined by substituting 1 into n_W and n_B in Eqs. 1 and 2, respectively, on condition that an external voltage is applied between the electrodes 28 and 26, and that no potential gradient is occurring in the i-layer 18. The quantum-wave interference layer functions as a carrier reflecting layer opposite to the carrier transmission layer. The present inventor has clarified the function and the structure of the carrier reflecting layer as shown in U.S. Patent Application No. 09/059,374. The second layers B which contact to the n-layer 16 and the p-layer 20 have thickness of 0.05 μm, respectively, to prevent electron from tunneling.

Measured I-V characteristic of the light-receiving device 200 is shown in FIG. 10. When light incided, the

photocurrent rises abruptly from 10^{-11} A to 10^{-7} A, or in the range of 4 orders, at the forward voltage of 0.2 V. But the photocurrent of the light-receiving device 200, 10^{-7} A, is smaller compared with the photocurrent of the light-receiving device 100, 10^{-5} A, shown in FIG. 9. When an applied voltage is very small, electric current does not flow in the light-receiving device 200. On the contrary, electric current flows in the light-receiving device 100 in Example 1, by applying a small value of forward voltage.

Comparing with Example 1 and this comparative example, V-I characteristic difference between the photocurrent and the dark current, and V-I characteristic difference between Example 1 and the comparative example are found to occur not because of a multi quantum-well structure itself but because of thicknesses of each layers in the multi quantum-well interference structure. Accordingly, a quantum-wave interference layer, functioning as a carrier transmitting layer which transmits carriers at a high velocity, can be obtained in the multi quantum-wave structure of the present invention.

In the embodiment, four quantum-wave interference layers Q_1 to Q_4 are connected in series, with each of the carrier confinement layers C_1 to C_3 lying between each of the quantum-wave interference layers. Alternatively, two quantum-wave interference layer units and one carrier accumulated layer therebetween can be formed in the i-layer at least.

In the embodiment, a δ layer is formed in the device 100. The δ layer enables to vary the band gap energy at a potential interface sharply and improves the quantum-wave interference effect (transmittivity) of the devices. Alternatively, although the quantum-wave interference effect declines, the δ layer is not necessarily needed.

Further, in the Example 1, the quantum-wave interference layer unit and the δ layer was made of ternary compounds including $Ga_{0.51}In_{0.49}P/Al_{0.51}In_{0.49}P$ and quaternary compounds including $Al_{0.33}Ga_{0.33}In_{0.33}P$, respectively. Alternatively, the quantum-wave interference layer units and a δ layer can be made of quaternary compounds such as $Al_xGa_yIn_{1-x-y}P$ or $Al_xGa_yIn_{1-x-y}As$, selecting arbitrary composition ratio within the range of $0 \leqq x \leqq 1$, $0 \leqq y \leqq 1$, and $0 \leqq x+y \leqq 1$.

As another alternative, the quantum-wave interference layer can be made of group III-V compound semiconductor, group II-VI compound semiconductors, Si and Ge, and semiconductors of other hetero-material. The desirable compositions are as follows. Each combinations is represented by a composition of a layer having a wide band width / a layer having a narrow band width // a substrate. And x and y are arbitrary values wherein $0 \leqq x \leqq 1$ and $0 \leqq y \leqq 1$, as long as they are not specified.

<1> $Al_xIn_{1-x}P$ / $Ga_yIn_{1-y}P$ // GaAs

<2> $Al_xGa_{1-x}As$ / GaAs // GaAs

<3> $Ga_xIn_{1-x}P$ / InP // InP

<4> $Ga_xIn_{1-x}P$ / $Ga_xIn_{1-x}As$ // GaAs

<5> AlAs / $Al_xGa_{1-x}As$ // GaAs ($0.8 \leqq x \leqq 0.9$)

<6> InP / $Ga_xIn_{1-x}As_yP_{1-y}$ // GaAs

<7> Si / $SiGe_x$ // arbitrary material ($0.1 \leqq x \leqq 0.3$)

<8> Si / $SiGe_xC_y$ // arbitrary material ($0.1 \leqq x \leqq 0.3$, $0 < y \leqq 0.1$)

<9> $Al_{x1}Ga_{y1}In_{1-x1-y1}N$ / $Al_{x2}Ga_{y2}In_{1-x2-y2}N$ // Si, SiC, GaN, or sapphire ($0 \leqq x_1$, x_2, y_1, y_2, x_1+y_1, $x_2+y_2 \leqq 1$)

While the invention has been described in connection with what are presently considered to be the most practical and preferred embodiments, it is to be understood that the invention is not to be limited to the disclosed embodiments, but on the contrary, the description is intended to cover various modifications and equivalent arrangements included within the spirit and scope of the appended claims. The present document claims the benefit of Japanese priority document, filed in Japan on December 17, 1998, the entire contents of which is incorporated herein by reference.

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

WHAT IS CLAIMED IS:

1. A light-receiving device which converts an incident light into an electric current, comprising:

quantum-wave interference layer units having plural periods of a pair of a first layer and a second layer, said second layer having a wider band gap than said first layer;

a carrier accumulation layer disposed between adjacent two of said quantum-wave interference layer units; and

wherein each thickness of said first and said second layers is determined by multiplying by an even number one fourth of quantum-wave wavelength of carriers in each of said first and said second layers and said carrier accumulation layer has a band gap narrower than that of said second layer.

2. A light-receiving device according to claim 1, wherein a kinetic energy of said carriers which determines said quantum-wave wavelength is set at a level near the bottom of a conduction band and a valence band of said second layer, according to the case that said carriers are electrons and holes, respectively.

3. A light-receiving device according to claim 1, wherein a quantum-wave wavelength λ_W in said first layer is determined by a formula $\lambda_W = h/[2m_W(E+V)]^{1/2}$, a quantum-wave wavelength λ_B in said second layer is determined by a formula $\lambda_B = h/(2m_B E)^{1/2}$, said thickness of said first layer

D_W is determined by a formula $D_W = n_W \lambda_W/4$, and said thickness of said second layer D_B is determined by a formula $D_B = n_B \lambda_B/4$, where h, m_W, m_B, E, V, and n_W and n_B represent Plank's constant, effective mass of said carrier in said first layer, effective mass of said carrier in said second layer, kinetic energy of carriers flowing into said second layer, potential energy of said second layer to said first layer, and even numbers, respectively.

4. A light-receiving device according to claim 2, wherein a quantum-wave wavelength λ_W in said first layer is determined by a formula $\lambda_W = h/[2m_W(E+V)]^{1/2}$, a quantum-wave wavelength λ_B in said second layer is determined by a formula $\lambda_B = h/(2m_B E)^{1/2}$, said thickness of said first layer D_W is determined by a formula $D_W = n_W \lambda_W/4$, and said thickness of said second layer D_B is determined by a formula $D_B = n_B \lambda_B/4$, where h, m_W, m_B, E, V, and n_W and n_B represent Plank's constant, effective mass of said carrier in said first layer, effective mass of said carrier in said second layer, kinetic energy of carriers flowing into said second layer, potential energy of said second layer to said first layer, and even numbers, respectively.

5. A light-receiving device according to claim 1 comprising:

a plurality of partial quantum-wave interference layer I_k with T_k periods of a pair of said first layer and said

second layer being displaced in series by varying k as 1, 2, …, and

wherein index k of said plurality of said partial quantum-wave interference layers correspond to index k of kinetic energy level E_k and said first and second layers have thicknesses of $n_{Wk}\lambda_{Wk}/4$, and $n_{Bk}\lambda_{Bk}/4$, respectively, where E_k+V and E_k, λ_{Wk} and λ_{Bk}, and n_{Wk}, n_{Bk} represent kinetic energy level of carriers flowing into respective said first layer and said second layer, wavelength of quantum-wave of carriers flowing into respective said first layer and said second layer, and even numbers, respectively, and λ_{Wk} and λ_{Bk} are determined by functions of E_k+V and E_k, respectively.

6. A light-receiving device according to claim 2 comprising:

a plurality of partial quantum-wave interference layer I_k with T_k periods of a pair of said first layer and said second layer being displaced in series by varying k as 1, 2, …, and

wherein index k of said plurality of said partial quantum-wave interference layers correspond to index k of kinetic energy level E_k and said first and second layers have thicknesses of $n_{Wk}\lambda_{Wk}/4$, and $n_{Bk}\lambda_{Bk}/4$, respectively, where E_k+V and E_k, λ_{Wk} and λ_{Bk}, and n_{Wk}, n_{Bk} represent kinetic energy level of carriers flowing into respective said first layer and said second layer, wavelength of quantum-wave of carriers flowing into respective said first layer and said

second layer, and even numbers, respectively, and λ_{Wk} and λ_{Bk} are determined by functions of E_k+V and E_k, respectively.

7. A light-receiving device according to claim 1, wherein said carrier accumulation layer has the same bandwidth as that of said first layer.

8. A light-receiving device according to claim 3, wherein said carrier accumulation layer has the same bandwidth as that of said first layer.

9. A light-receiving device according to claim 5, wherein said carrier accumulation layer has the same bandwidth as that of said first layer.

10. A light-receiving device according to claim 3, wherein said carrier accumulation layer is formed to have a thickness same as said quantum-wave wavelength λ_W.

11. A light-receiving device according to claim 8, wherein said carrier accumulation layer is formed to have a thickness same as said quantum-wave wavelength λ_W.

12. A light-receiving device according to claim 9, wherein said carrier accumulation layer is formed to have a thickness same as said quantum-wave wavelength λ_W.

13. A light-receiving device according to claim 1, wherein a δ layer is formed between said first layer and said second layer, said δ layer is substantially thinner than said first layer and said second layer, and sharply varies an energy band.

14. A light-receiving device according to claim 3, wherein a δ layer is formed between said first layer and said second layer, said δ layer is substantially thinner than said first layer and said second layer, and sharply varies an energy band.

15. A light-receiving device according to claim 8, wherein a δ layer is formed between said first layer and said second layer, said δ layer is substantially thinner than said first layer and said second layer, and sharply varies an energy band.

16. A light-receiving device according to claim 10, wherein a δ layer is formed between said first layer and said second layer, said δ layer is substantially thinner than said first layer and said second layer, and sharply varies an energy band.

17. A light-receiving device according to claim 1 further comprising:

a pin junction structure; and

wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an i-layer.

18. A light-receiving device according to claim 3 further comprising:

a pin junction structure; and

wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an i-layer.

19. A light-receiving device according to claim 5 further comprising:

a pin junction structure; and

wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an i-layer.

20. A light-receiving device according to claim 8 further comprising:

a pin junction structure; and

wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an i-layer.

21. A light-receiving device according to claim 10 further comprising:

a pin junction structure; and

wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an i-layer.

22. A light-receiving device according to claim 1, wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an n-layer or a p-layer.

23. A light-receiving device according to claim 3, wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an n-layer or a p-layer.

24. A light-receiving device according to claim 5, wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an n-layer or a p-layer.

25. A light-receiving device according to claim 8, wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an n-layer or a p-layer.

26. A light-receiving device according to claim 10, wherein said quantum-wave interference layer units and said carrier accumulation layer are formed in an n-layer or a p-layer.

27. A light-receiving device according to claim 22, further comprising a pn junction structure.

28. A light-receiving device according to claim 23, further comprising a pn junction structure.

29. A light-receiving device according to claim 24, further comprising a pn junction structure.

30. A light-receiving device according to claim 25, further comprising a pn junction structure.

31. A light-receiving device according to claim 26, further comprising a pn junction structure.

ABSTRACT OF THE DISCLOSURE

A light-receiving device of a pin junction structure, constituted by a quantum-wave interference layers Q_1 to Q_4 with plural periods of a pair of a first layer W and a second layer B and carrier accumulation layers C_1 to C_3. The second layer B has wider band gap than the first layer W. Each thicknesses of the first layer W and the second layer B is determined by multiplying by an even number one fourth of wavelength of quantum-wave of carriers in each of the first layer W and the second layer B existing at the level near the lowest energy level of the second layer B. A δ layer, for sharply varying energy band, is formed at an every interface between the first layer W and the second layer B and has a thickness substantially thinner than the first layer W and the second layer B. As a result, when electrons are excited in the carrier accumulation layers C_1 to C_3, electrons are propagated through the quantum-wave interference layer from the n-layer to the p-layer as a wave, and electric current flows rapidly.

FIG. 1

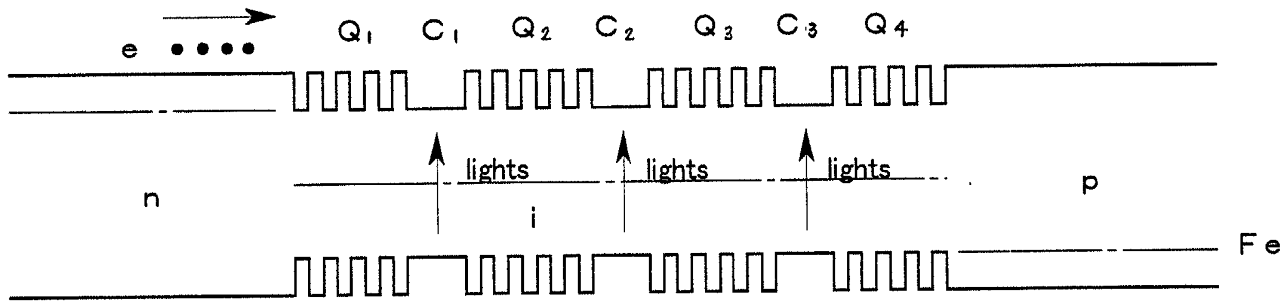

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FIG. 2

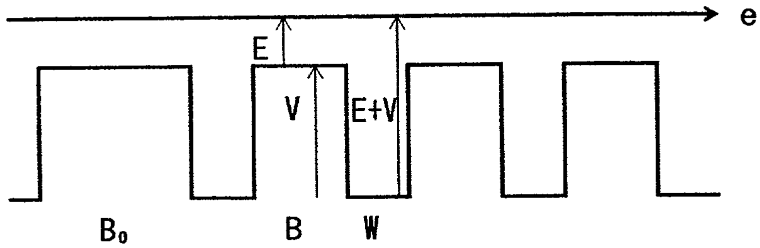


FIG. 3

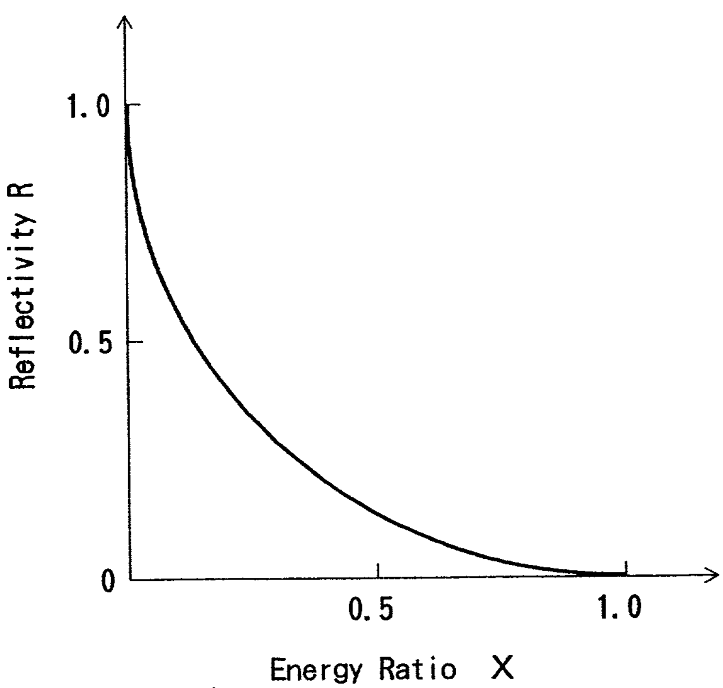


FIG. 4A

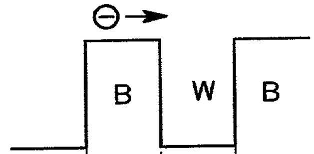


FIG. 4B

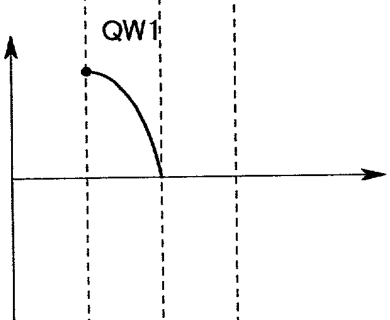


FIG. 4C

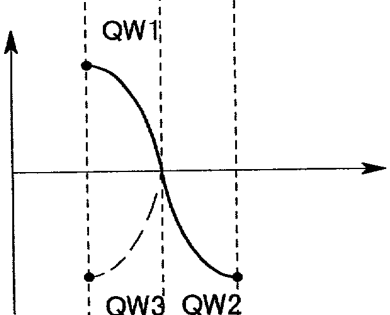


FIG. 4D

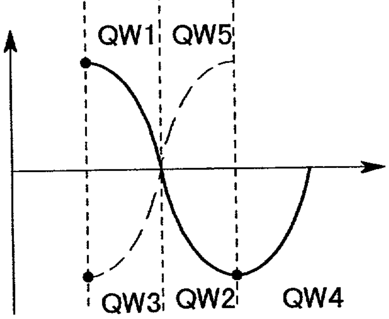


FIG. 4E

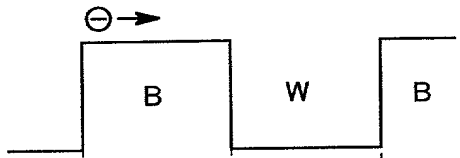


FIG. 4F

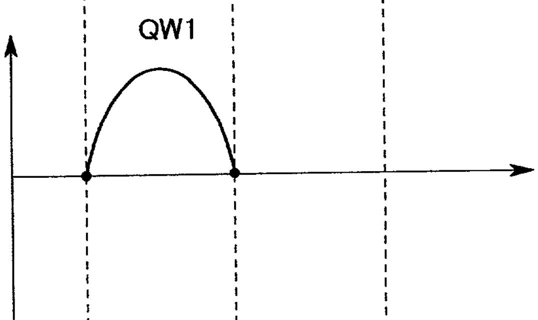


FIG. 4G

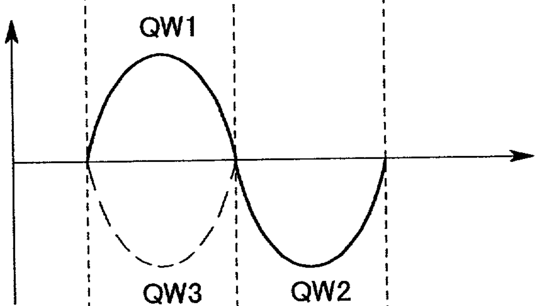


FIG. 4H

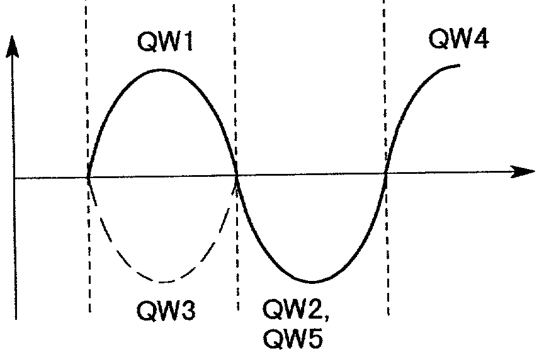


FIG. 5

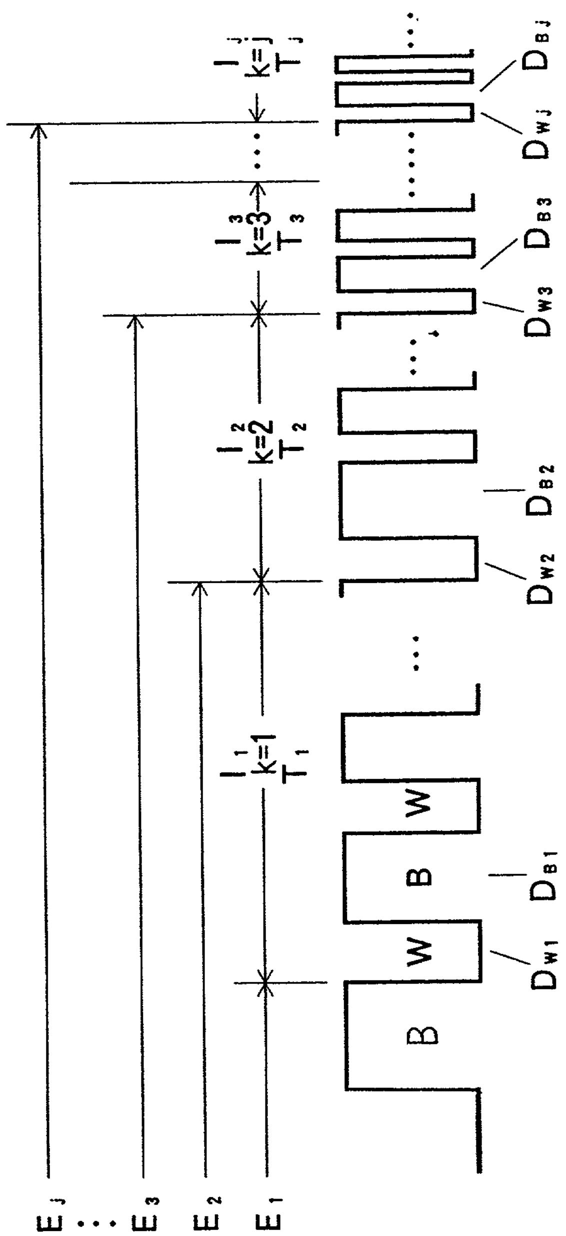

E1
E2
E3
Ej
l1 k=1 T1
l2 k=2 T2
l3 k=3 T3
lj k=j Tj
B
W
B
W
DW1
DB1
DW2
DB2
DW3
DB3
DWj
DBj

FIG. 6A

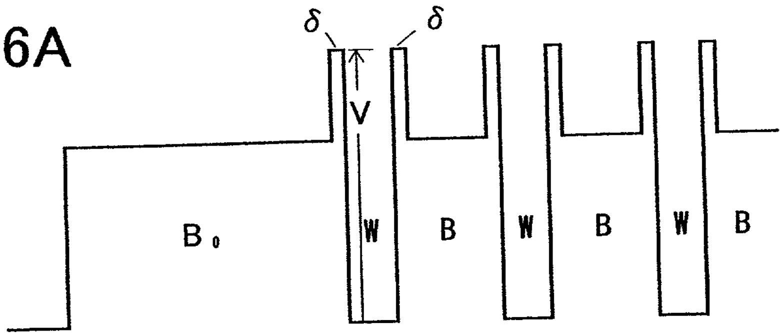


FIG. 6B

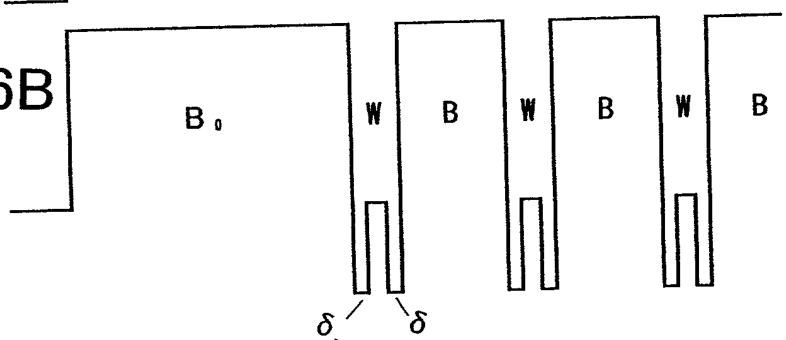


FIG. 6C

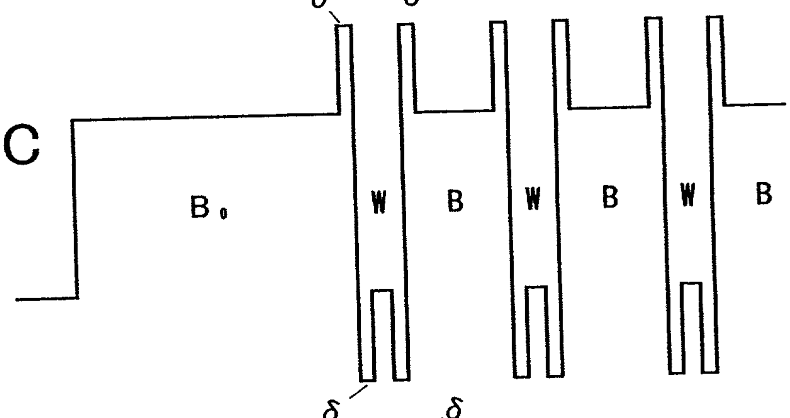


FIG. 6D

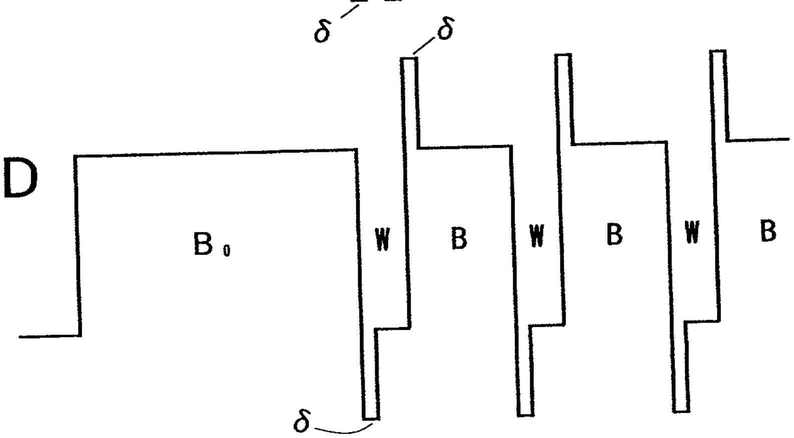


FIG. 7A

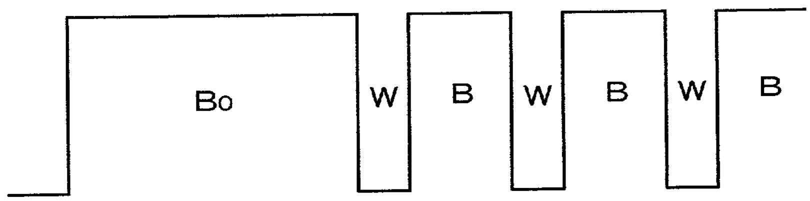


FIG. 7B

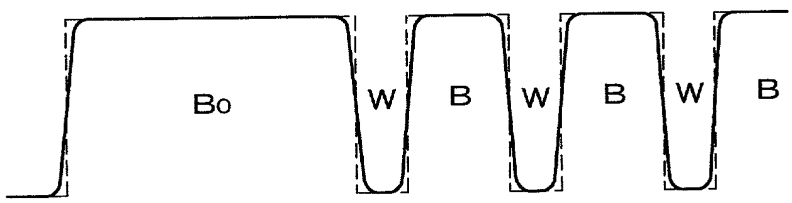


FIG. 7C

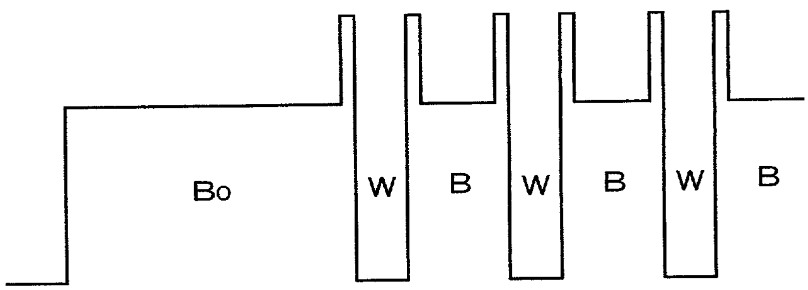


FIG. 7D

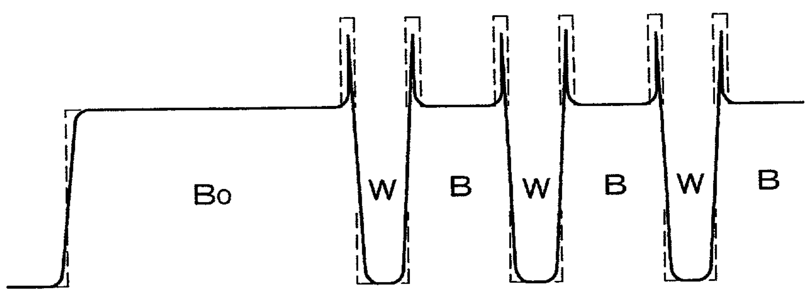


FIG. 8

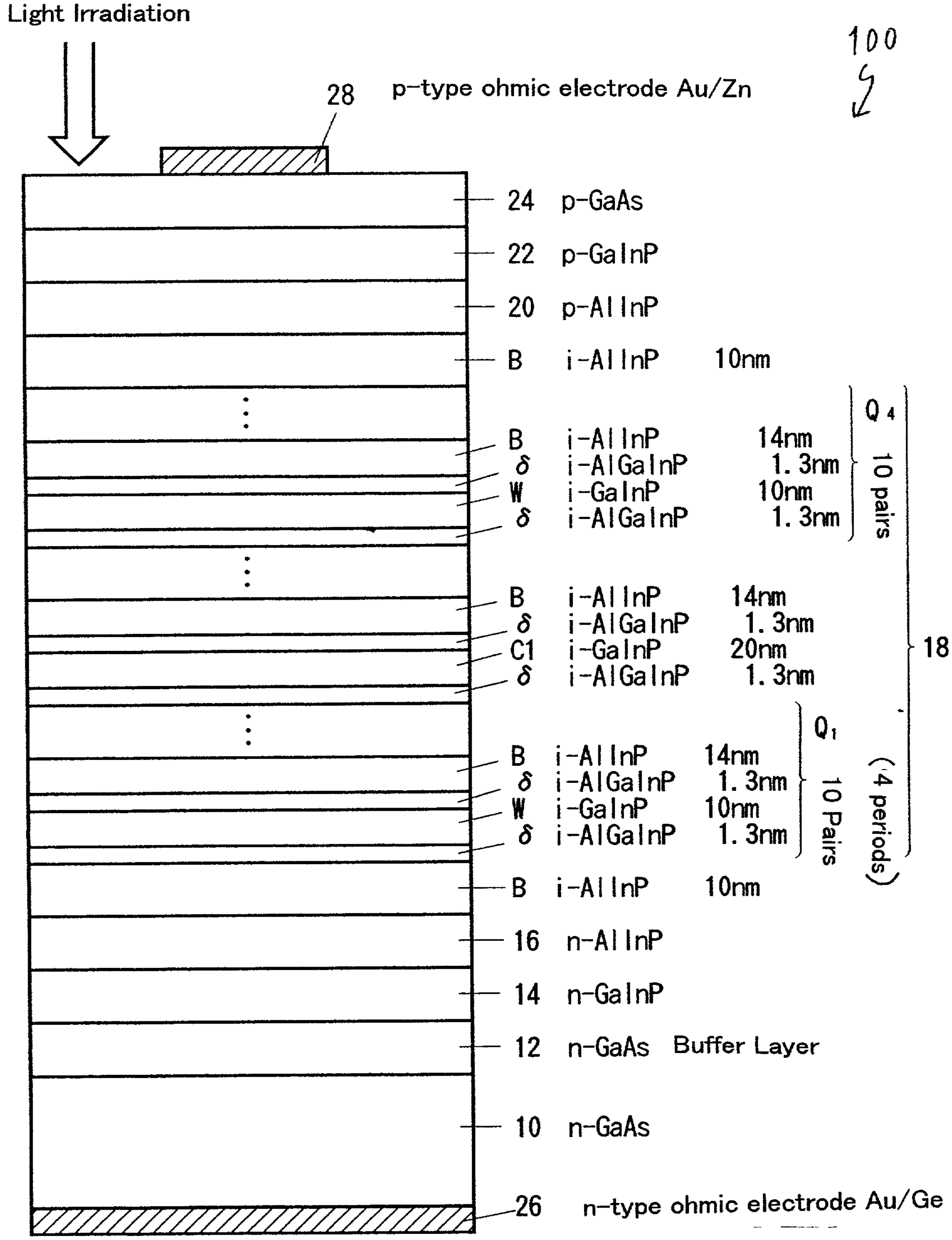

Light Irradiation
100
28 p-type ohmic electrode Au/Zn
24 p-GaAs
22 p-GaInP
20 p-AlInP
B i-AlInP 10nm
B i-AlInP 14nm
δ i-AlGaInP 1.3nm
W i-GaInP 10nm
δ i-AlGaInP 1.3nm
Q4
10 pairs
B i-AlInP 14nm
δ i-AlGaInP 1.3nm
C1 i-GaInP 20nm
δ i-AlGaInP 1.3nm
18
B i-AlInP 14nm
δ i-AlGaInP 1.3nm
W i-GaInP 10nm
δ i-AlGaInP 1.3nm
Q1
10 Pairs
(4 periods)
B i-AlInP 10nm
16 n-AlInP
14 n-GaInP
12 n-GaAs Buffer Layer
10 n-GaAs
26 n-type ohmic electrode Au/Ge

FIG. 9

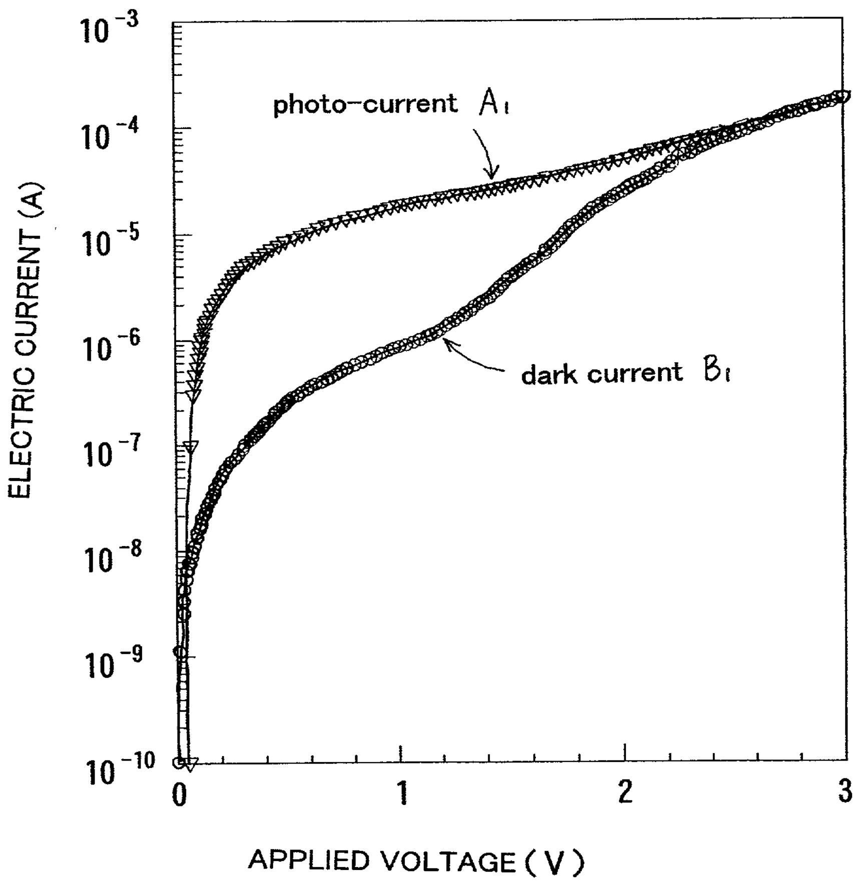
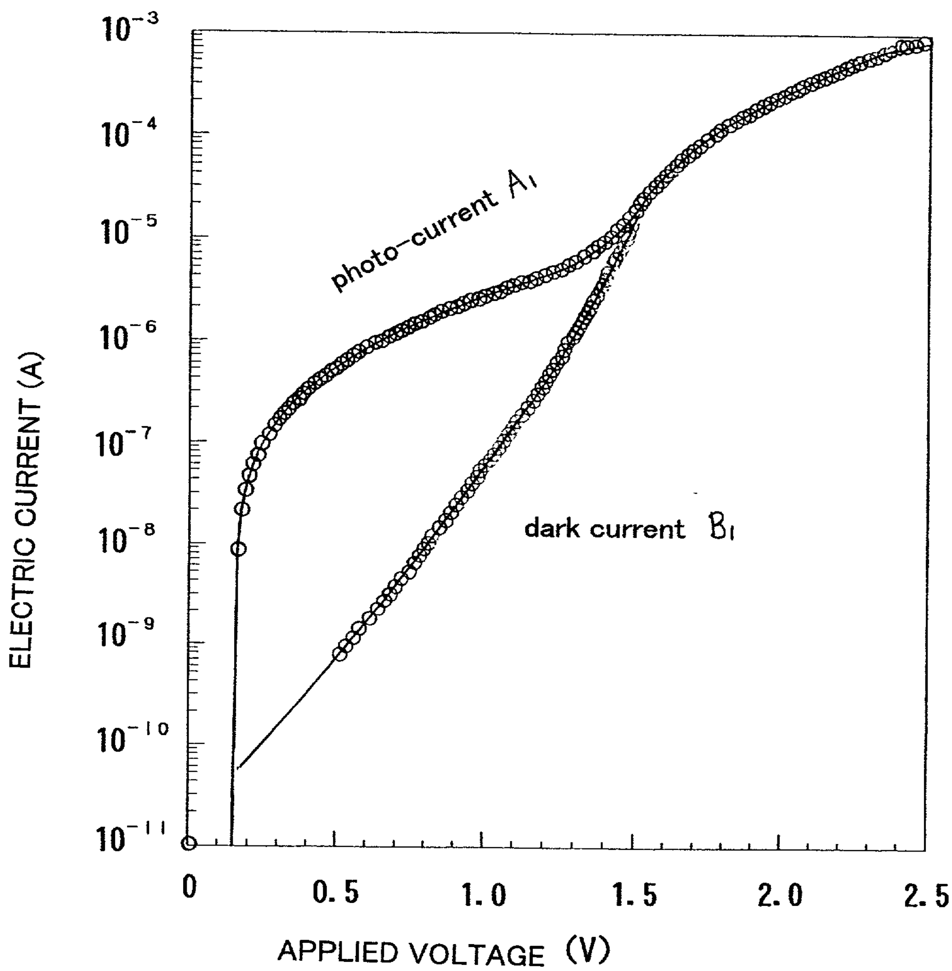

10 −3
10 −4
10 −5
10 −6
10 −7
10 −8
10 −9
10 −10
ELECTRIC CURRENT (A)
photo-current A1
dark current B1
0
1
2
3
APPLIED VOLTAGE (V)

FIG. 10


10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
10^-11
ELECTRIC CURRENT (A)
photo-current A1
dark current B1
0
0.5
1.0
1.5
2.0
2.5
APPLIED VOLTAGE (V)

H44-173-US ①
(H10-358935. 12/17)

Declaration and Power of Attorney For Patent Application

特許出願宣言書及び委任状

Japanese Language Declaration

日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者（下記の名称が複数の場合）であると信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled.

LIGHT-RECEIVING DEVICE WITH QUANTUM-WAVE INTERFERENCE LAYERS

上記発明の明細書は、

☐ 本書に添付されています。

☐ ___月___日に提出され、米国出願番号または特許協定条約国際出願番号を__________とし、(該当する場合) __________に訂正されました。

the specification of which

☑ is attached hereto.

☐ was filed on ____________________ as United States Application Number or PCT International Application Number __________ and was amended on __________ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第37編第1条56項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration
(日本語宣言書)

私は、米国法典第35編119条（a）-（d）項又は365条（b）項に基づき下記の、米国以外の国の少なくとも一ヵ国を指定している特許協力条約365（a）項に基づく国際出願、又は外国での特許出願もしくは発明者証の出願についての外国優先権をここに主張するとともに、優先権を主張している、本出願の前に出願された特許または発明者証の外国出願を以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119 (a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

(Number) (番号)	(Country) (国名)	(Day/Month/Year Filed) (出願年月日)	Priority Claimed 優先権主張	
H10-358935	JAPAN	17/December/1998	☒ Yes はい	☐ No いいえ
			☐ Yes はい	☐ No いいえ

私は、第35編米国法典119条（e）項に基づいて下記の米国特許出願規定に記載された権利をここに主張いたします。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Application No.) (出願番号)	(Filing Date) (出願日)

私は、下記の米国法典第35編120条に基づいて下記の米国特許出願に記載された権利、又は米国を指定している特許協力条約365条（c）に基づく権利をここに主張します。また、本出願の各請求範囲の内容が米国法典第35編112条第1項又は特許協力条約で規定された方法で先行する米国特許出願に開示されていない限り、その先行米国出願書提出日以降で本出願書の日本国内または特許協力条約国際提出日までの期間中に入手された、連邦規則法典第37編1条56項で定義された特許資格の有無に関する重要な情報について開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or Section 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of application.

(Application No.) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現況：特許許可済、係属中、放棄済)

私は、私自信の知識に基づいて本宣言書中で私が行なう表明が真実であり、かつ私の入手した情報と私の信じるところに基づく表明が全て真実であると信じていること、さらに故意になされた虚偽の表明及びそれと同等の行為は米国法典第18編第1001条に基づき、罰金または拘禁、もしくはその両方により処罰されること、そしてそのような故意による虚偽の声明を行なえば、出願した、又は既に許可された特許の有効性が失われることを認識し、よってここに上記のごとく宣誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

F99-173-US ③

Japanese Language Declaration
（日本語宣言書）

委任状：私は下記の発明者として、本出願に関する一切の手続きを米特許商標局に対して遂行する弁理士または代理人として、下記の者を指名いたします。
（弁護士、または代理人の指名及び登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: *(list name and registration number)*

Norman F. Oblon, Reg. No. 24,618; Marvin J. Spivak, Reg. No. 24,913; C. Irvin McClelland, Reg. No. 21,124; Gregory J. Maier, Reg. No. 25,599; Arthur I. Neustadt, Reg. No. 24,854; Richard D. Kelly, Reg. No. 27,757; James D. Hamilton, Reg. No. 28,421; Eckhard H. Kuesters, Reg. No. 28,870; Robert T. Pous, Reg. No. 29,099; Charles L. Gholz, Reg. No. 26,395; Vincent J. Sunderdick, Reg. No. 29,004; William E. Beaumont, Reg. No. 30,996; Robert F. Gnuse, Reg. No. 27,295; Jean-Paul Lavalleye, Reg. No. 31,451; Stephen G. Baxter, Reg. No. 32,884; Martin M. Zoltick, Reg. No. 35,745; Robert W. Hahl, Reg. No. 33,893; Richard L. Treanor, Reg. No. 36,379; Steven P. Weihrouch, Reg. No. 32,829; John T. Goolkasian, Reg. No. 26, 142; Richard L. Chinn, Reg. No. 34,305; Steven E. Lipman, Reg. No. 30,011; Carl E. Schlier, Reg. No. 34,426; James J. Kulbaski, Reg. No. 34,648; Richard A. Neifeld, Reg. No. 35,299; J. Derek Mason, Reg. No. 35,270; Surinder Sachar, Reg. No. 34,423; Christina M. Gadiano, Reg. No. 37,628; Jeffrey B. McIntyre, Reg. No. 36,867; and Paul E. Rauch, Reg. No. 38,591 with full powers of substitution and revocation.

書類送付先

Send Correspondence to:

OBLON, SPIVAK, McCLELLAND, MAIER & NEUSTADT, P.C.
FOURTH FLOOR
1755 JEFFERSON DAVIS HIGHWAY
ARLINGTON, VIRGINIA 22202 U.S.A.

直接電話連絡先：（名前及び電話番号）

Direct Telephone Calls to: (name and telephone number)
(703) 413-3000

単独発明者または第一の共同発明者の氏名	Full name of sole or first joint inventor Hiroyuki KANO
発明者の署名　日付	Inventor's signature　Date Hiroyuki Kano　26/Nov./99
住所	Residence same as below
国籍	Citizenship JAPAN
郵便の宛先	Post Office Address 18B3, 1237-87, Umazutsumi, Kurozasa,
	Miyoshi-cho, Nishikamo-gun, Aichi-ken, 470-0201, JAPAN
第二の共同発明者の氏名	Full name of second joint inventor, if any
第二の共同発明者の署名　日付	Second joint Inventor's signature　Date
住所	Residence
国籍	Citizenship
郵便の宛先	Post Office Address

（第三以降の共同発明者についても同様に記載し、署名すること）

(Supply similar information and signature for third and subsequent joint inventors.)

3/99